Recommendations Emerging from an Analysis of NASA's Deep Space Communications Capacity

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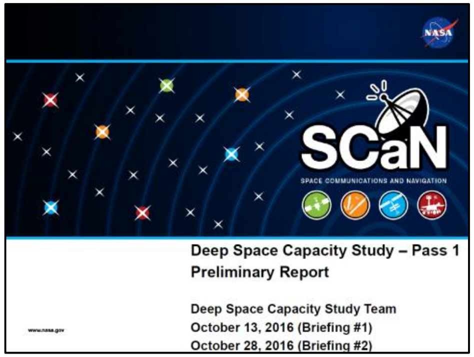
SpaceOps 2018
Marseille, France

May 30, 2018

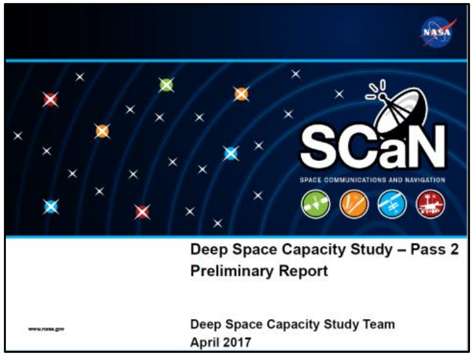
Background

- 2016: NASA's Space Communications and Navigation (SCaN) Office chartered a "Deep Space Capacity Study."
- Purpose: To provide a basis for formulating a deep space communications and navigation investment strategy.



Pass-1 (Fall 2016)

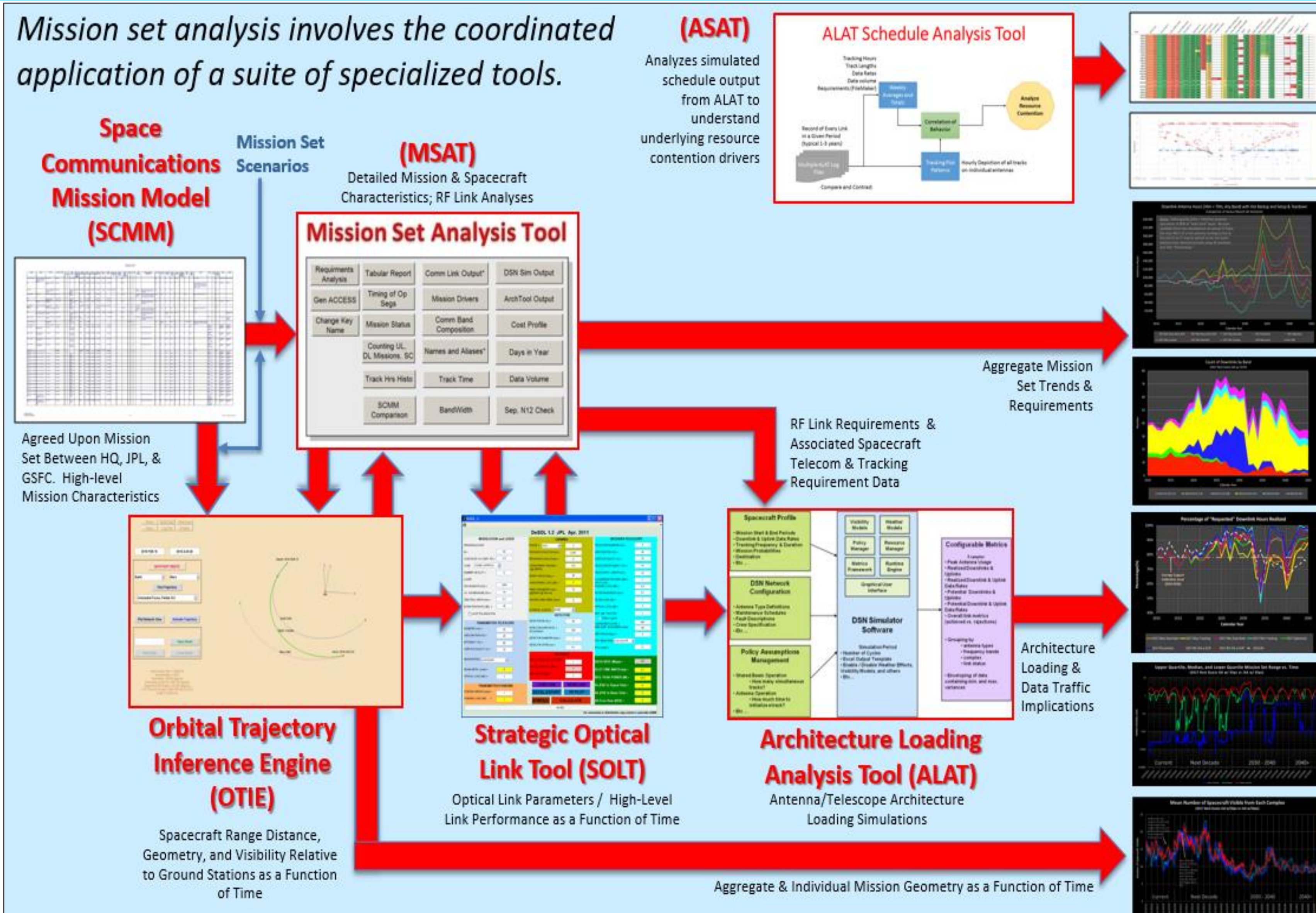
- 30-year capacity demand projection
- Identification and analysis of supply shortfalls
- Initial concepts for eliminating shortfalls



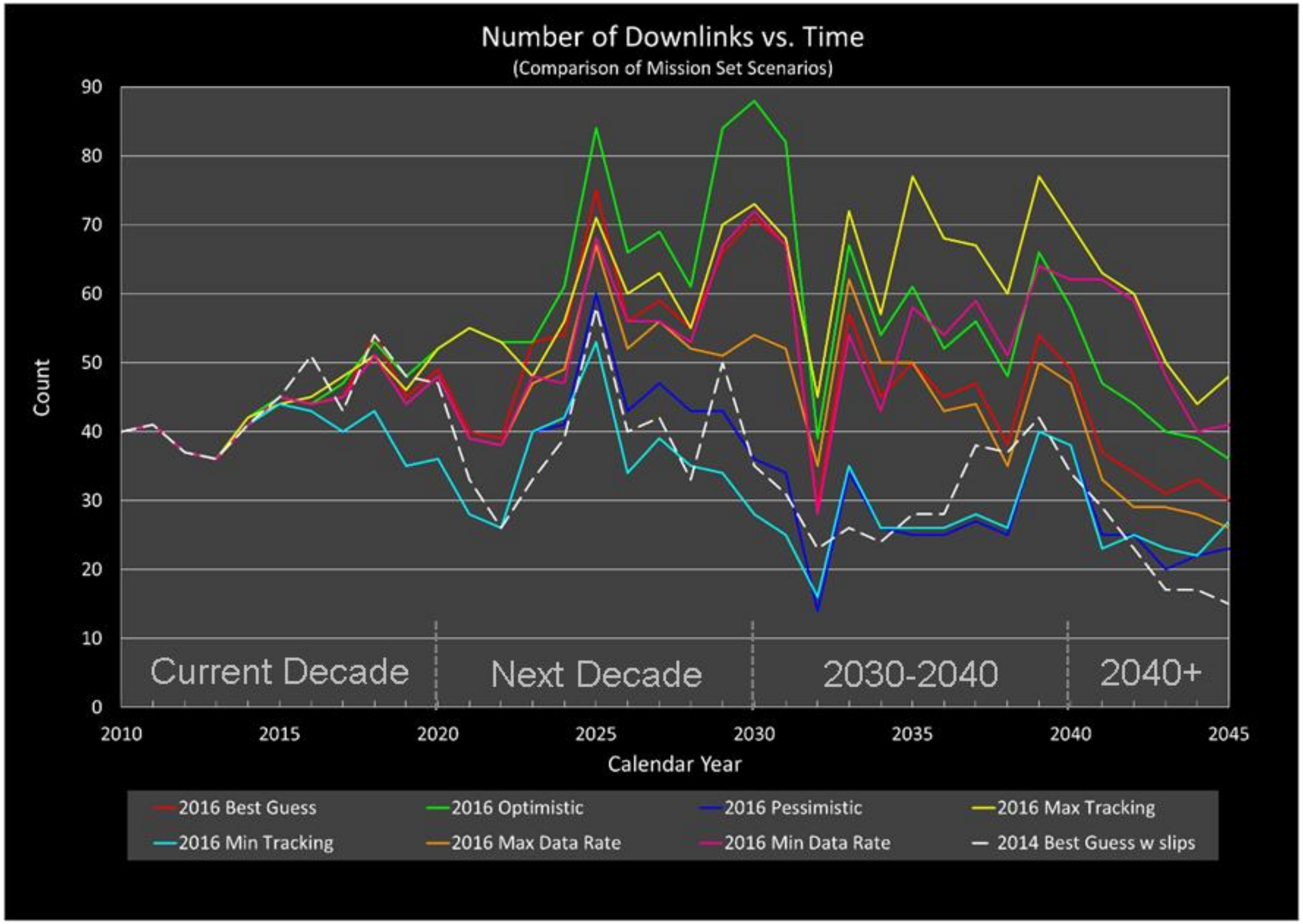
Pass-2 (Spring 2017)

- Seek more cost-effective concepts for eliminating capacity shortfalls
- "Flesh out" the most promising concepts

Projecting Future Mission Needs

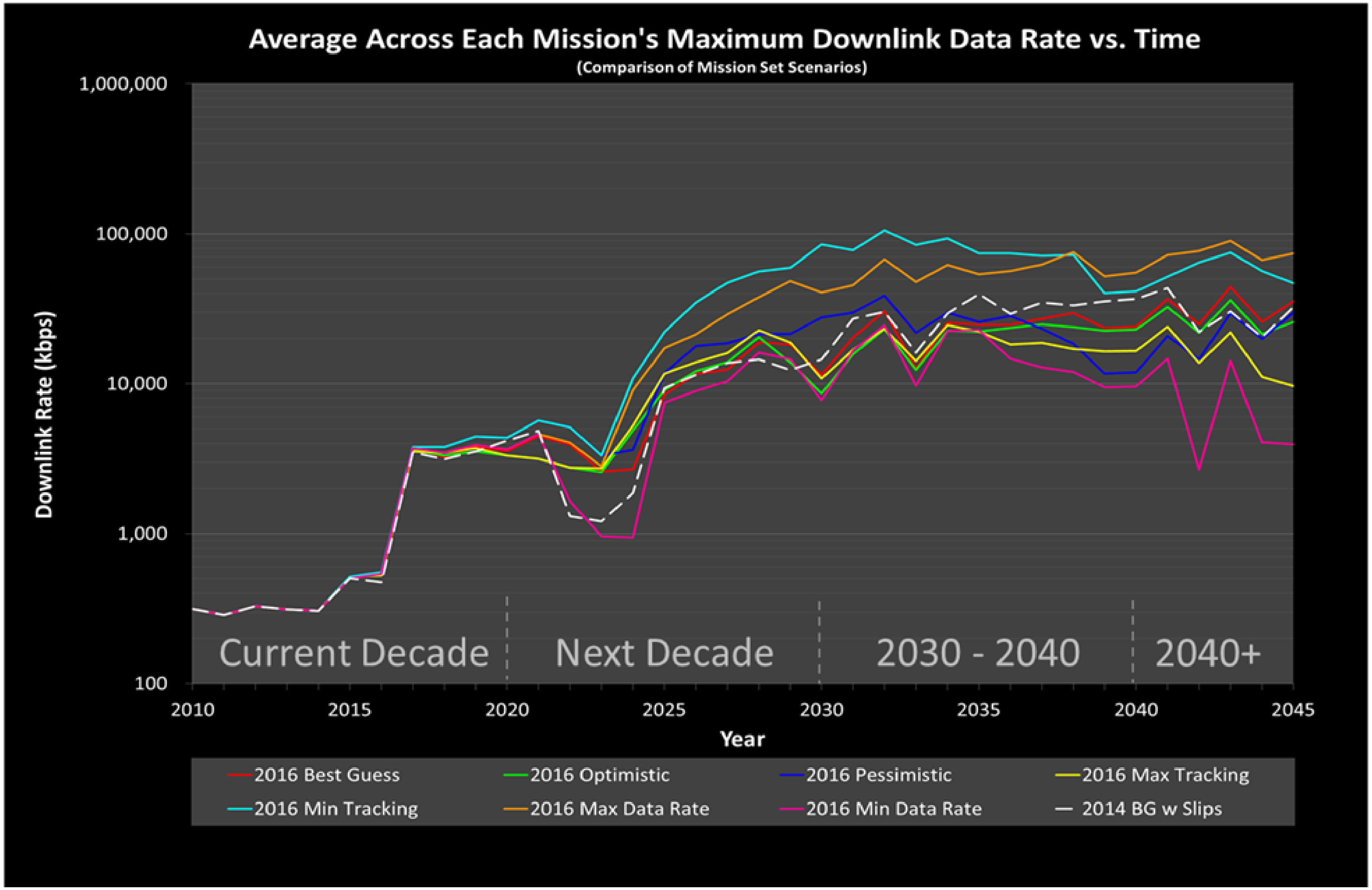


Key Trends (1/4)



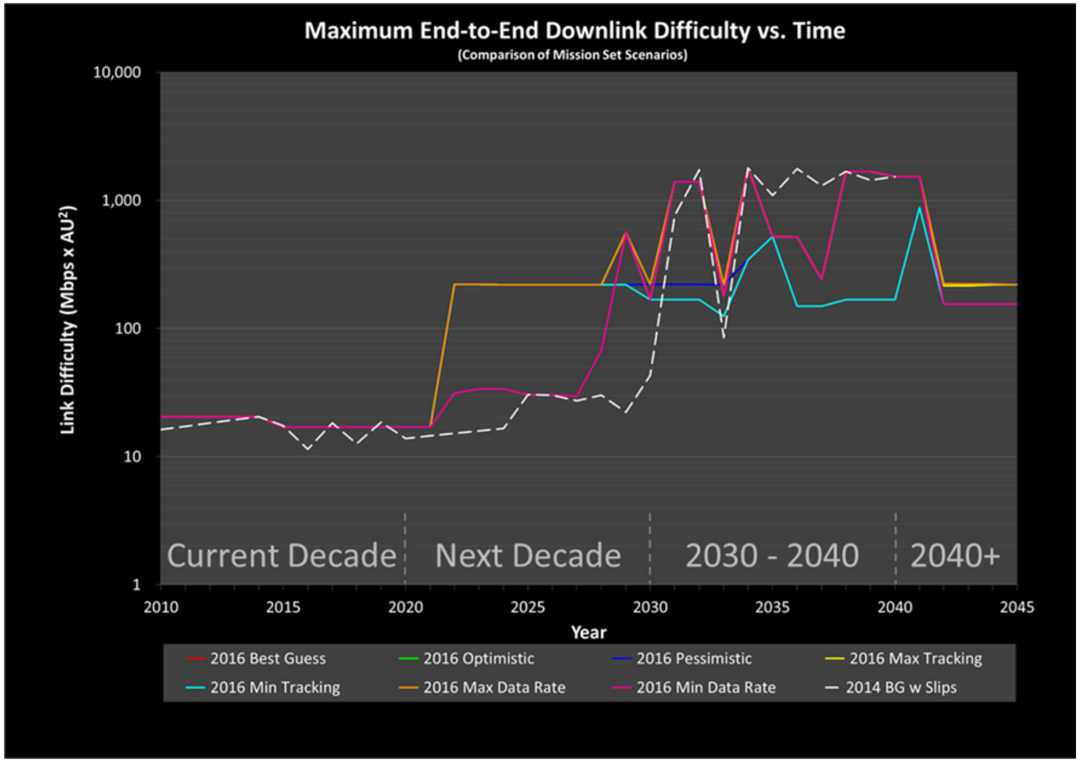
In most scenarios, the number of downlinks (and associated spacecraft) increase dramatically in the next decade.

Key Trends (2/4)



Average data rates increase significantly over the next decade, leveling off as link difficulties and RF bandwidth allocation constraints become formidable.

Key Trends (3/4)



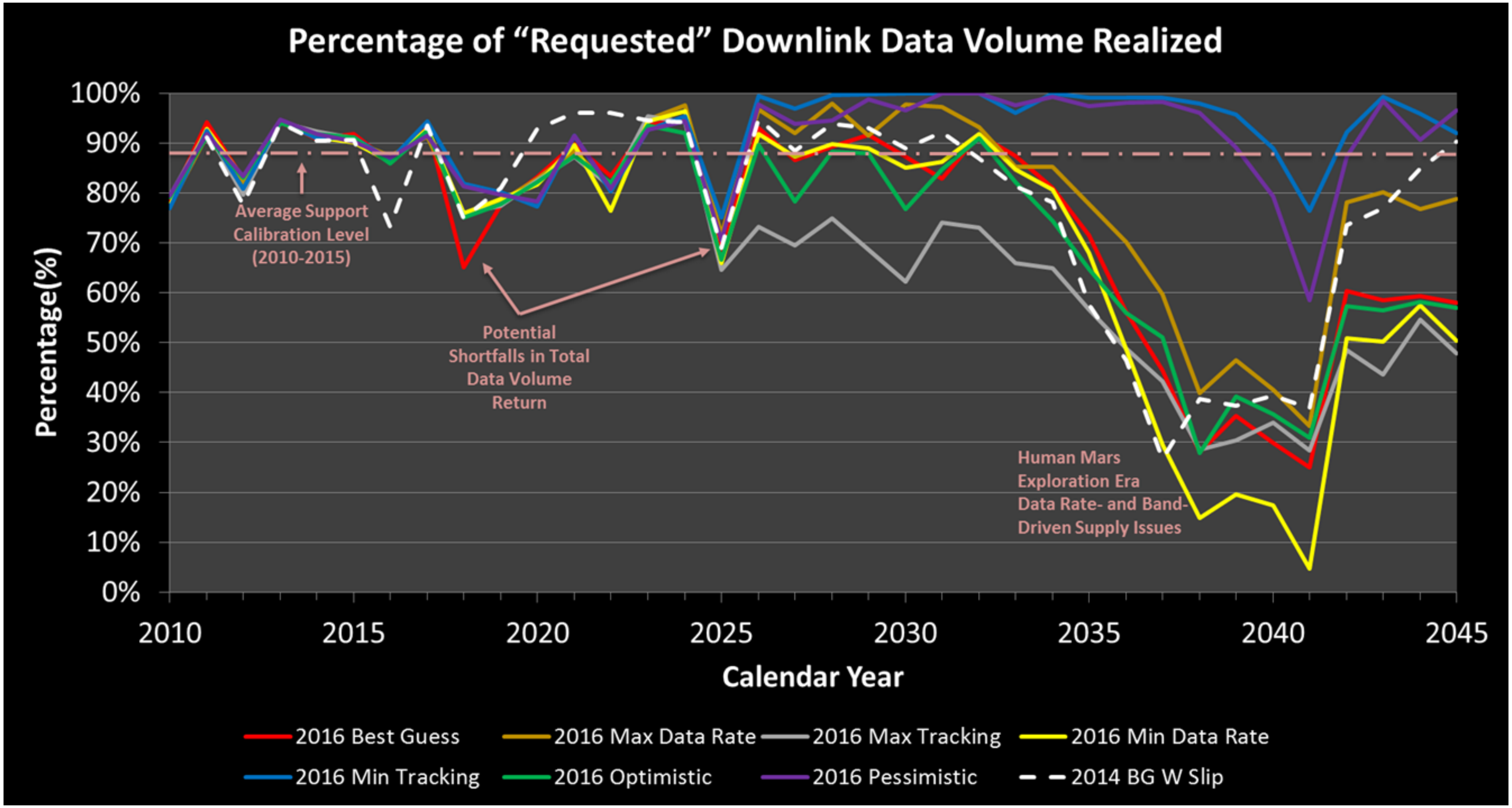
High data rates at long link distances drive large end-to-end link difficulties.

At RF, this necessitates arraying antennas which "eats" into available capacity.

	Range from Earth (AU)	Number of 34m Antennas
Mars Average (Time-based)	1.71	2.89 -> 3; plus 1 "hot" backup
Max Mars (50 yrs)	2.66	6; plus 1 "hot" backup
Min Mars (50 yrs)	0.38	0.14 -> 1; plus 1 "hot" backup

Number of 34m antennas needed to close link with a Mars Areostationary Relay satellite transmitting at 250 Mbps via a 500W transmitter and a 6m HGA

Key Trends (4/4)



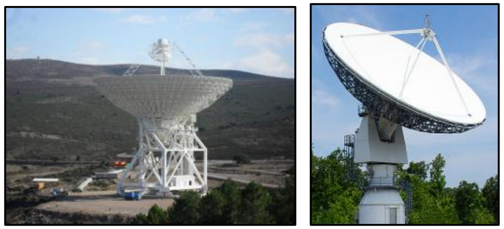
Loading simulations show asset contention in the 2020s and major capacity shortfalls beginning in the 2030s – when the more demanding individual links require more arrayed antennas than are available at a given Complex.

Addressing the Shortfalls (1/5)

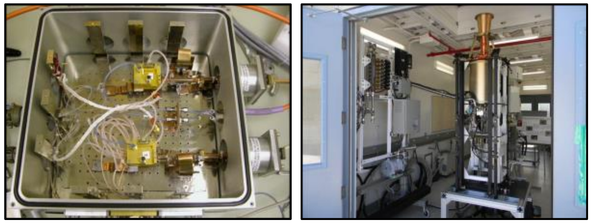
Pass-1 Solutions

- **For Asset Contention in the 2020's:**

+



International and University Cross-Support



Adding Additional Frequency Band Capabilities on Existing Antennas

- **For Asset Contention in the 2030's and beyond:**

7 New 34m BWGs Per Complex
Operating as an Array

\+ **2020 Pass-1 Measures**

or

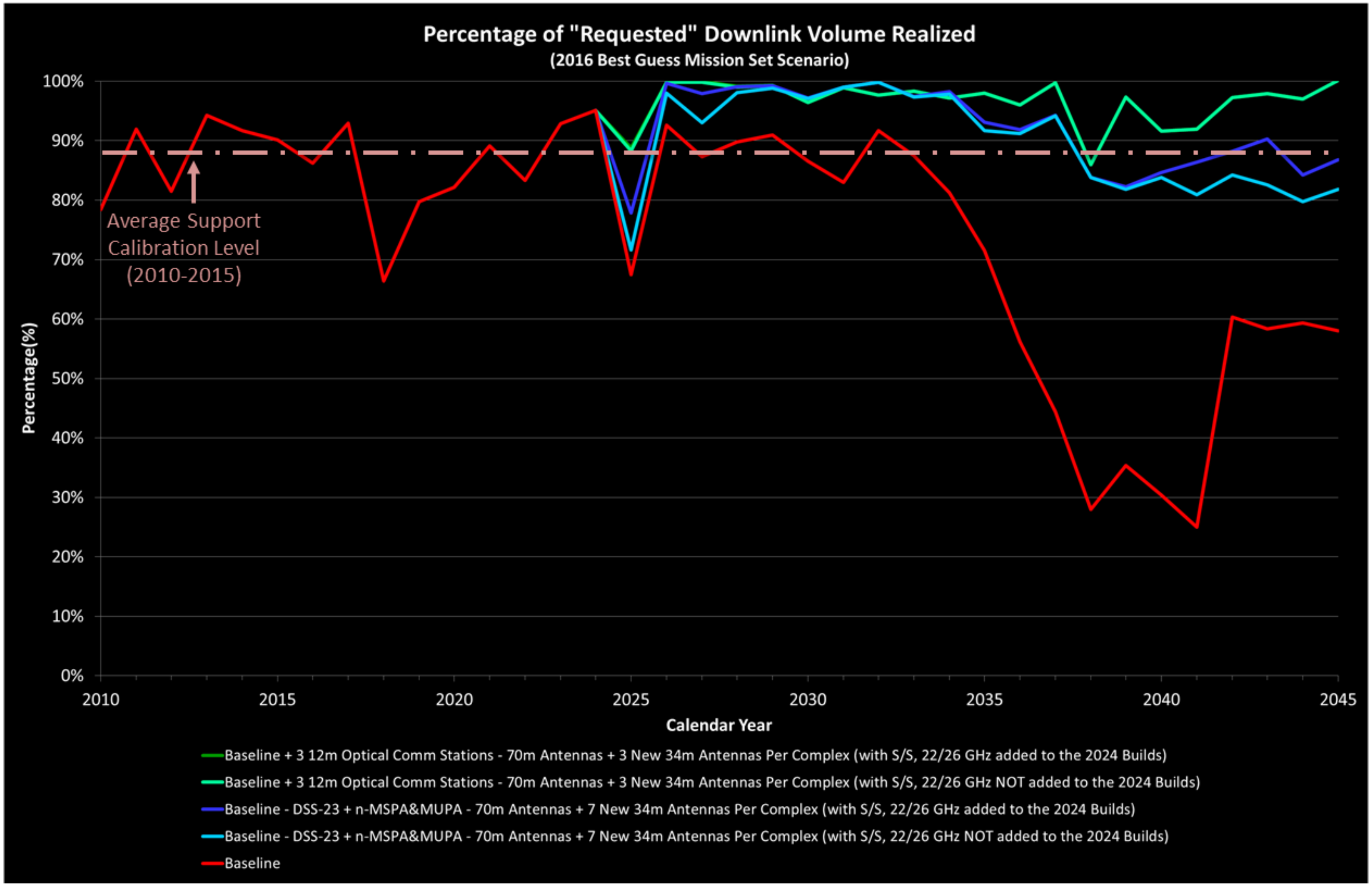
3 New 34m BWGs Per Complex
Operating as an Array
(esp. for uplink)

\+

1 New 12m Optical Ground Station

\+ **2020 Pass-1 Measures**

Addressing the Shortfalls (2/5)

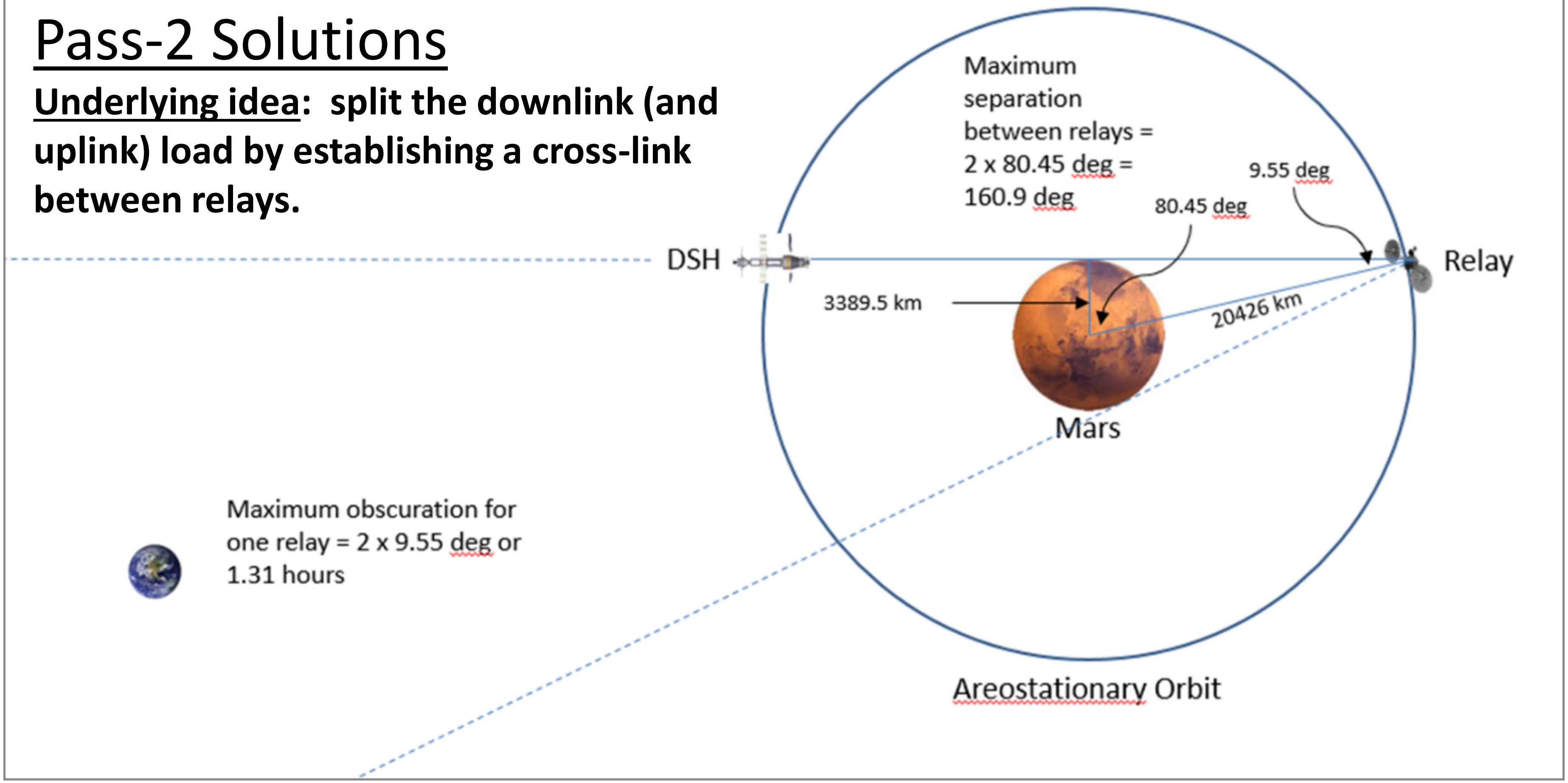


Either the RF or Combined RF-Optical approaches satisfied most of the downlink volume demand – though, the RF-Optical performed the best.

Addressing the Shortfalls (3/5)

Pass-2 Solutions

Underlying idea: split the downlink (and uplink) load by establishing a cross-link between relays.

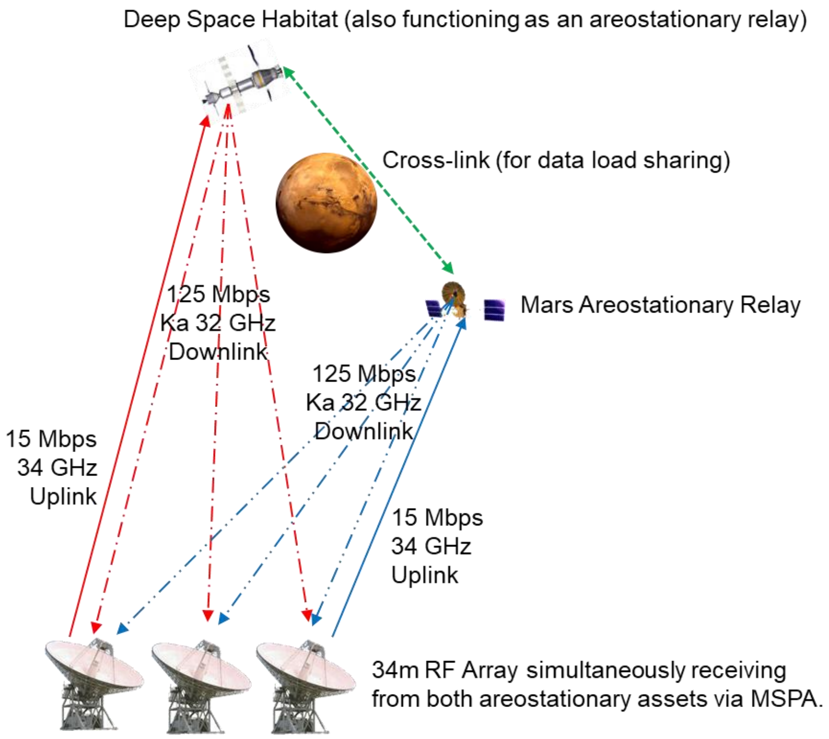


A cross-link between the two areostationary relays allows "dual-trunk links" to send back the same total volume of data at half the data rate – hence, requiring half the G/T on the ground, provided both trunk links are MSPA'd.

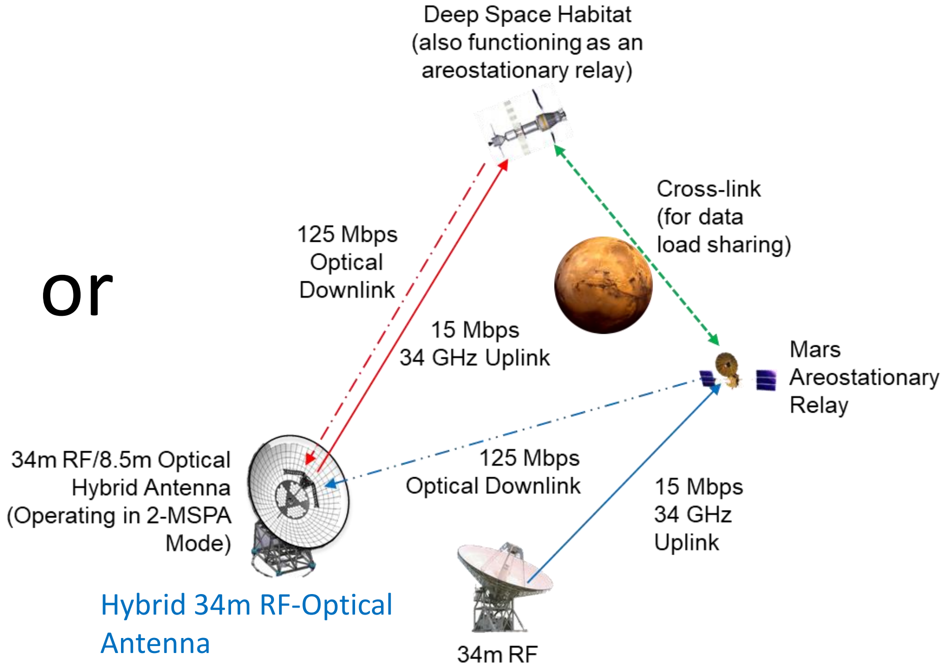
Addressing the Shortfalls (4/5)

Pass-2 Solutions

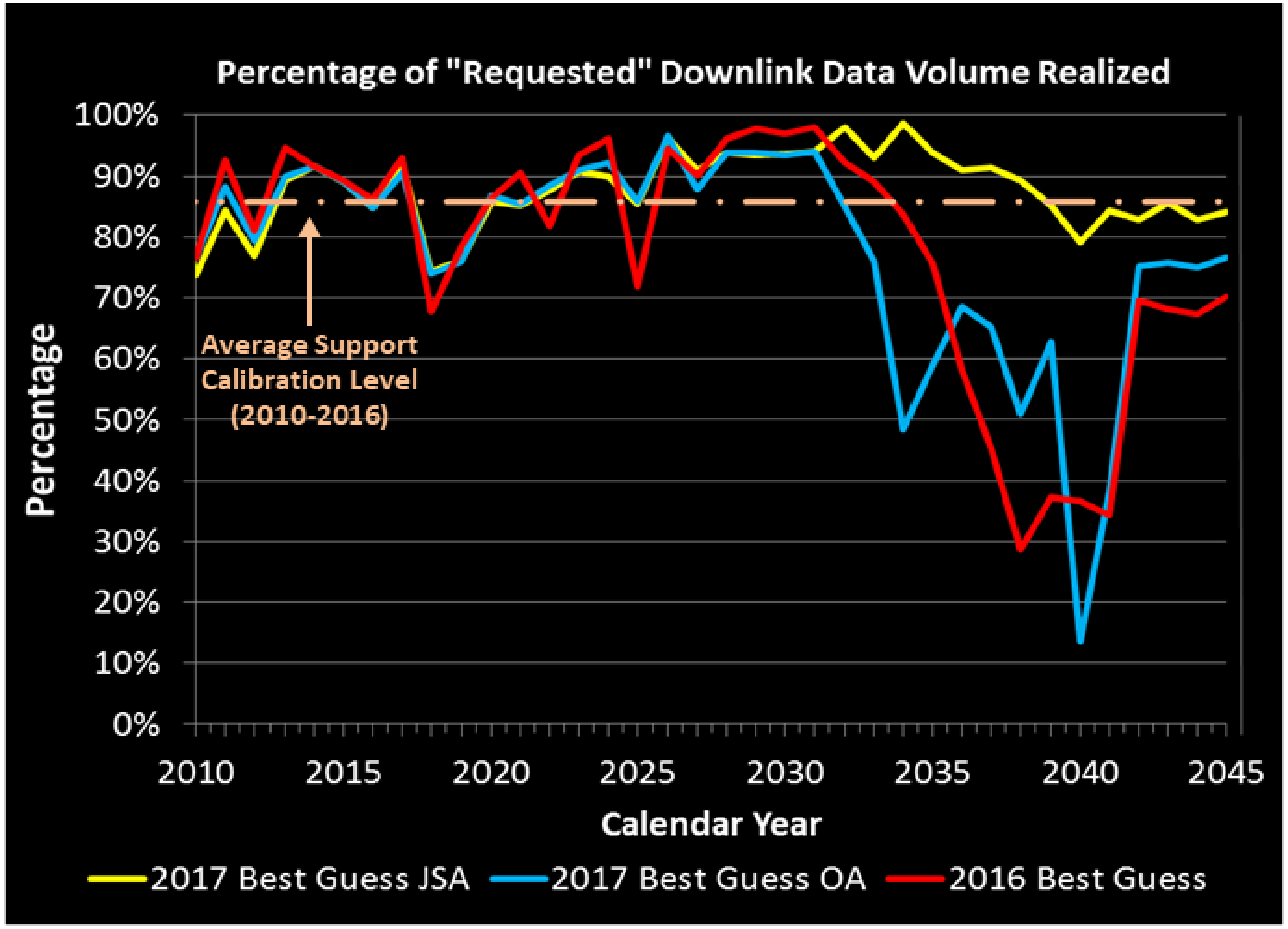
- **For Asset Contention in the 2020's:** **Same as for Pass-1**
- **For Shortfalls in the 2030's and Beyond:** **For details see Wallace Tai's "Mars Planetary Network for Human Exploration Era"**



or



Addressing the Shortfalls (5/5)



"2017 Best Guess JSA" embodies the Pass-2 solutions – aggregate mission set requirements are satisfied.

Recommendations

- Driver: Steep increase in number of spacecraft requiring DSN support in next 10 years
  - Develop and maximize use of beam sharing (n-MSPA, OMSPA, MUPA).
  - Add additional bands (e.g., 22/26 GHz) to some existing antennas to achieve greater scheduling flexibility.
  - Foster international and university cross-support.
- Driver: Steep increase in data rates over next 10 years
  - Develop ability to array up antennas at Ka-band to close RF links.
  - Develop optical communications capability (e.g., RF-optical hybrids antennas) to ease RF antenna demand and circumvent allocated-RF-spectrum constraints.
- Driver: Beyond 2030, human exploration drives data rates on trunk link to/from Earth.
  - Develop cross-links for use between relays to load-share and use dual-trunk links back to Earth to keep required data rates at manageable levels.
- Doing all of the above takes a long time. Start now.